MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ETM2126 – INFORMATION THEORY AND ERROR CONTROL CODING

(TE)

04 MARCH 2017

2:30 P.M – 4:30 P.M.

(2 Hours)

INSTRUCTIONS TO STUDENT:

1. This exam paper consists of **5 pages** with **4 questions.**
2. Attempt **ALL questions**. All questions have equal weightage and the breakdown of marks within each question is given.
3. Please write all your answers in the answer booklet provided. Show all relevant steps to obtain maximum marks

Question 1

(a) Consider a source with 5 possible symbols. Suppose the probabilities of the first 4 symbols are 0.3, 0.25, 0.18, and 0.09.

i. Design a Huffman code for this source (using as-high-as-possible strategy).

[7 marks]

ii. Compute the average codeword length.

[3 marks]

iii. The source entropy is calculated as 2.2244 bits. Explain why the average codeword length of the Huffman code is quite close to the source entropy.

[3 marks]

(b) Suppose we want to encode the *Kamus Dewan* (a Malay language dictionary) which contains about 49,000 entries.

i. Describe 3 possible problems if each word is encoded as a 16-bit number.

[6 marks]

ii. Consider the sequence of Malay words below:

abad_abah_abang_abu...

Use Lempel-Ziv algorithm to construct the code dictionary according to the format given in **Table 1**.

[6 marks]

Table 1

Location	Content	Codeword

Continued...

Question 2

(a) Consider a communication channel with a model given in **Figure 2.1**.

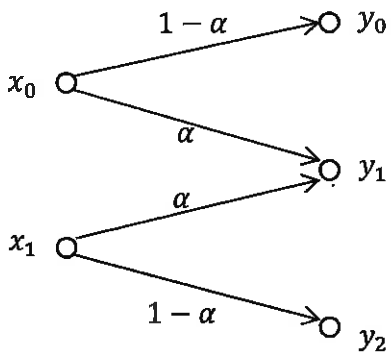

Figure 2.1

i. It can be shown that the mutual information of this channel is maximized when $p(x_0) = p(x_1) = 0.5$. Find the channel capacity if $\alpha = 0.1$.

[10 marks]

ii. Can the channel capacity be improved by changing the value of α? Explain your answer.

[3 marks]

(b) A communications channel (which is a Gaussian noise channel) has a bandwidth of 4 kHz and signal-to-noise ratio of 7. The Gaussian noise has a power spectral density $\frac{N_0}{2} = 10\ \mu W/Hz$. If the bandwidth is reduced by 25%, how much should the signal power be increased to maintain the same channel capacity?

[6 marks]

(c) The bandwidth efficiency diagram is shown in **Figure 2.2**.

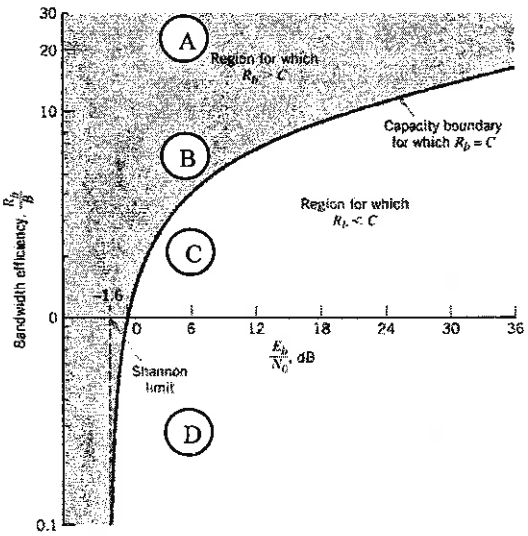

Figure 2.2

Continued...

Suppose we have a communication system with fixed transmission power and bandwidth. Select the best operating region from the 4 possible regions (A, B, C, D) indicated in Figure 2.2. Justify your answer.

[6 marks]

Question 3

(a) The generator matrix for a linear block code is given by

$$\mathbf{G} = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

i. Encode the message 1010. How many parity bits are used in this code?

[4 marks]

ii. Determine the corresponding parity-check matrix.

[2 marks]

iii. Suppose the vector 11111000 is received and it contains one error bit. Apply syndrome decoding to detect and correct the error.

[9 marks]

(b) The generator polynomial for a (7,4) cyclic Hamming code is given by

$$g(D) = 1 + D + D^3$$

i. Encode the message $m(D) = 1 + D^2 + D^3$. Give your answer in binary bits form.

[3 marks]

ii. Suppose the following two codewords which may contain error(s) have been received:

$$y_1 = [1\ 0\ 1\ 1\ 1\ 0\ 0]$$

$$y_2 = [1\ 0\ 1\ 1\ 1\ 1\ 0]$$

Can syndrome decoding be used to detect and correct the error(s) in the two received vectors above?

[7 marks]

Continued...

Question 3

(a) The impulse responses that describe a convolutional encoder are given as follows:

$$\boldsymbol{g^{(1)} = [1\ 1\ 0]}, \qquad \boldsymbol{g^{(2)} = [1\ 0\ 1]}, \qquad \boldsymbol{g^{(3)} = [1\ 1\ 1]}$$

Suppose a message sequence is encoded using this code and is sent over a noisy channel. The received sequence is 010000100001000. Apply Viterbi algorithm to recover the transmitted message bits. Provide the following details in your answer:

- The trellis diagram
- Traces of the decisions on the diagram
- The survivors' Hamming distance metrics at each node level.

(Note: If a tie occurs in the metrics required for a decision, always choose the upper path)

[15 marks]

(b) A TCM is designed by using a rate 1/2 convolutional encoder. The generator polynomials of the convolutional encoder are given by

$$g^{(1)}(D) = 1, \qquad g^{(2)}(D) = 1 + D$$

The output bits of the convolutional encoder are mapped to one signal point of a QPSK signal set.

i. By using set partitioning approach, map the codewords to the signal points of the QPSK signal set illustrated in **Figure 4**.

[5 marks]

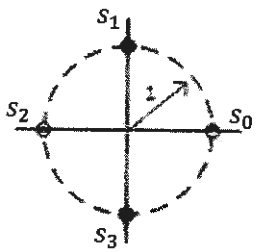

Figure 4

ii. What is the minimum squared Euclidean distance between the TCM coded sequence?

[5 marks]

End of paper.